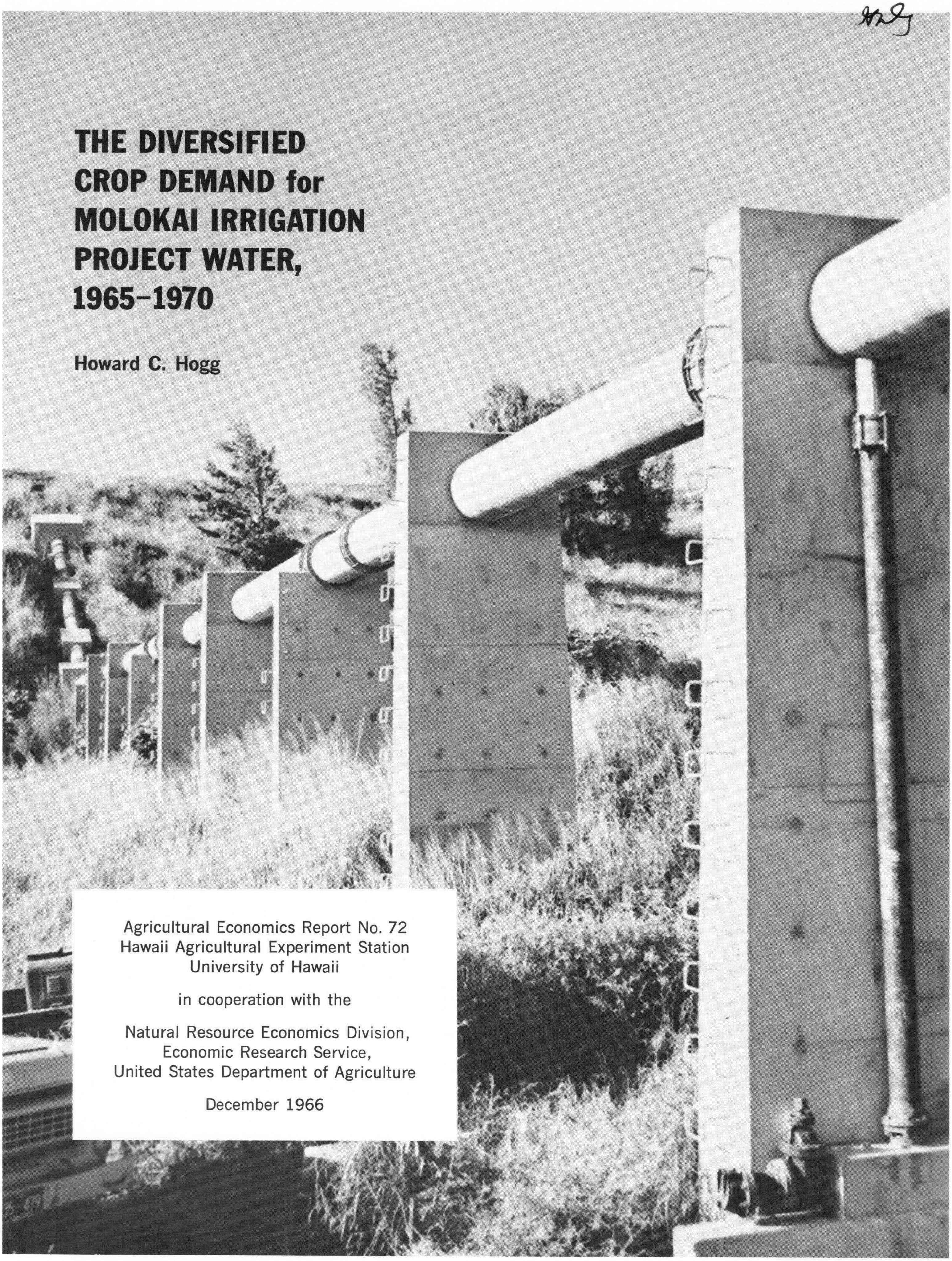

THE DIVERSIFIED CROP DEMAND for MOLOKAI IRRIGATION PROJECT WATER, 1965–1970

Howard C. Hogg

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Howard C. Hogg

INTRODUCTION

The Molokai irrigation project is a water development undertaking of the Division of Water and Land Development, Department of Land and Natural Resources, State of Hawaii. The purpose of the project is to develop unused water resources in Waikolu Valley for transfer to the semi-arid plains of Hoolehua and Mauna Loa, on the island of Molokai. Existing project facilities include diversion dams, wells, delivery conduits, a five-mile transfer tunnel, and a pipeline for delivering the water to Kualapuu. Under construction are a 1.4 billion-gallon storage reservoir at the Kualapuu end of the feeder line and distribution mains for Hoolehua (36, p. 67). The location of these facilities and the service areas are shown in Figure 1.[1/]

When completed, the project will be capable of irrigating 13,650 acres of cropland of which 6,150 acres are located in Hoolehua and 7,500 acres in Mauna Loa. Nearly all of the irrigated land will be employed in the production of pineapple. However, the Department of Land and Natural Resources controls approximately 1,000 acres of high-quality land in the Hoolehua service area. This parcel provides the basis for a potential agricultural subdivision consisting of small diversified farms. Effective development of this land, as part of the broader irrigation project, must be based on a knowledge of the diversifed crop demand for irrigation water and the amount of land that could be profitably used for diversified crop production with water priced at alternative rates.

RESEARCH PROCEDURE

The research procedure consisted of first preparing cost of production and yield estimates, by land productivity class, for those diversified crops that are suited to the project area. These commodities represent the production alternatives faced by potential project farmers. Market demand functions and supply functions for the existing producers of these crops were then estimated. This was done in an effort to duplicate the market forces that actually contribute to the establishment of a land use pattern under competitive conditions. Finally, these data were employed in an iterative linear programming model that indicates, by land quality, the project acreage that would be devoted to the production of each crop. This model is capable of accommodating several producing regions (which can be defined as areas of uniform physical productivity, because land classes within a project area are strict analogues of regions) and

1/ Unless otherwise specified, the numbers in parentheses refer to references listed at the end of the report.

Construction workers survey Waikolu Valley from tunnel portal at 1,000 feet.

State land at Hoolehua to be developed for farming.

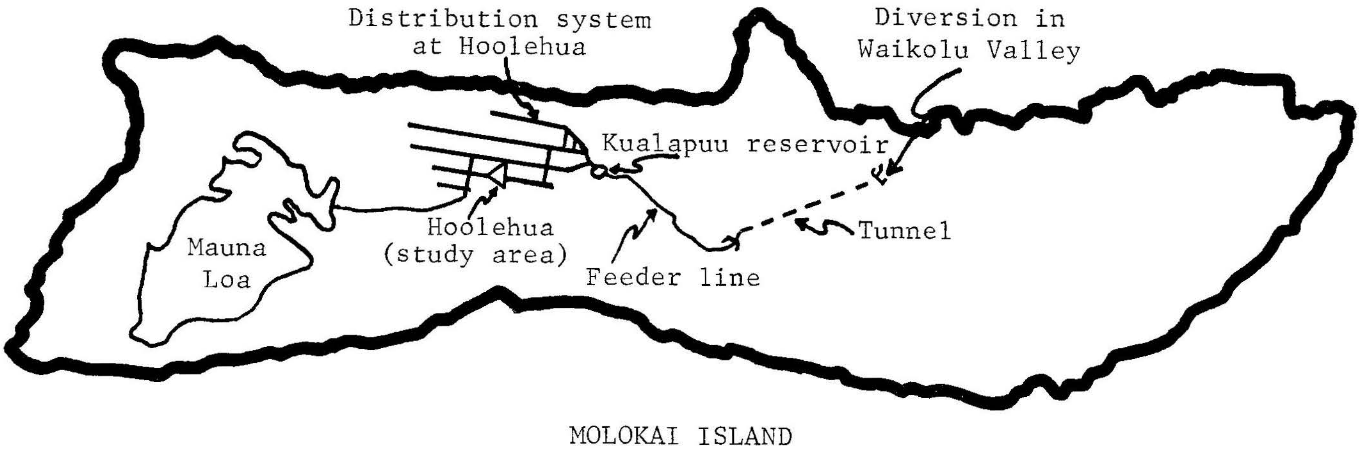


Figure 1. Location of physical facilities for the Molokai irrigation project.

Source: Department of Land and Natural Resources, State of Hawaii.

downward sloping demand functions for several commodities. Product prices and the quantities supplied by project farmers must be determined within the model so that each included commodity has an opportunity to compete for restrictive resources. The model also allows for adjustments in supply from existing producers as price changes and does not permit total production to exceed quantity demanded at any given price. A price-quantity relationship for water was derived by determining successive land use patterns while varying the price of water.

The estimating procedure, which has been described elsewhere (24), is a form of parametric programming. The procedure requires that prices be increased just enough in each successive program solution to cover the cost of production, including opportunity costs, on the next best land class until total market supply equals demand. If project land is exhausted before this requirement is satisfied, existing producers make up the difference. This process can be viewed as moving a market from an old equilibrium to a new one with the availability of project land shifting the existing supply function causing the new equilibrium to be established. The objective function consists of the net returns earned by each commodity on each land class.

The following four conditions must hold for an optimum solution:

1. Total market supply must equal demand simultaneously for all crops.

2. Market price is determined by production costs, including opportunity costs, on the least productive land used to produce each commodity.

3. Each land class earns a net return (rent) consistent with a single product price for each commodity exchanged in the market.

4. A single land class producing more than one commodity must earn the same net return in each use.

The basic assumptions of all linear programming problems, with the exception of constant product prices, apply in the present case. In addition, the following assumptions are made:

1. All producers of each commodity, on land of the same quality, have identical input-output coefficients.

2. All inputs except land are assumed to be available in unrestrictive quantities at a specific price.

3. The model is static, therefore, each solution refers to the market supply and demand of a single year.

4. Producers seek to maximize net returns in a competitive market.

5. The crops included in the model represent the entire range of production choices faced by prospective farmers in the project area.

6. The market demand and supply curves for existing producers are independent.

7. All project output is to be sold on the Honolulu market.

DESCRIPTION OF DATA

The data required for this study consist of production costs and yields by land productivity class, the acreage of each land class found in the project area, commodity demand curves, and supply curves for existing producers.

Land Productivity Classification

The land productivity classification used in this study is that developed by the Land Study Bureau, University of Hawaii (1, 30).

The productivity ratings for the lands found in the project area are given in Table 1. In the remainder of this study, land type 1i will be referred to as LC1 and the combined acreages of land types 3i and 17i as LC2. For the purposes of this report, these ratings are used as the basis for mapping areas of uniform physical quality.

Table 1. Land Types, Productivity Ratings, and Acreage of Project Lands

Location	Land Type[a/]	Productivity Ratings By Use[b/]				Acreage[c/]
Hoolehua	17i	1a	2a	6a	7a	2
	1i	1a	2b	6a	7a	678
	3i	1d	2c	6a	7b	219
	7i	1e	2e	6e	7e	152

a/ Those lands designated suitable for agricultural production are assumed to be irrigated. The individual land type descriptions are provided in Appendix A.

b/ Uses 1, 2, 6, and 7 represent pineapple, vegetables, pasture, and orchard crops, respectively. The lower case letters indicate the productivity of a land type in individual uses, with a designating the best land and e the poorest.

c/ Acreages were measured by planimeter from U. S. Geological Survey maps of a 1:25,000 scale.

Production Costs and Yields by Land Class

All but two of the crop budgets used in this report are based on existing cost-return studies. The two exceptions, field corn production and a combined hog-corn enterprise, were derived from mainland data and limited local experience. In some cases the data have been modified to insure comparability between commodities and to allow estimation of costs and yields over a range of land qualities. When the original budget does not distinguish between lands of different productivity, costs and yield adjustments were made by utilizing published materials dealing with the required cultural practices. Information obtained from interviews with Hawaii Agricultural Experiment Station, Hawaii Cooperative Extension Service, and industry specialists was also helpful in making these adjustments.

The following commodities were considered:

Vegetables	Orchard	Field Crops	Livestock
Tomatoes (6)	Papaya (21)	Corn (17)	Beef Production (15)
Manoa Lettuce (28)	Passion Fruit (19)		Combined Hog-Corn (17)
Snap Beans (26)	Guava (20)		
Cucumbers (5)	Brazilian Banana (22)		
Sweet Potatoes (26)			
Dry Onions (33)			
Irish Potatoes (33)			

Estimated costs and yields reflect typical management practices except that the unit size is 25 acres rather than the prevailing 4 to 5 acres. These budgets are available from the Department of Agricultural Economics, University of Hawaii, if detailed information about the different cost components is desired.

Irrigation requirements are estimated with a procedure developed by the Soil Conservation Service to meet conditions in Hawaii. To estimate irrigation requirements pan evaporation data and consumptive use coefficients are employed to determine the gross consumptive use for each crop. The gross consumptive use less effective rainfall is the required irrigation level. The estimated irrigation requirements are given in Appendix B.

Wind is a serious problem at Hoolehua. However, the Hawaii State Department of Land and Natural Resources will establish a system of permanent windbreaks before disposition of the units to diversified farmers. It is assumed that wind will be effectively controlled for vegetable production before farming begins, and that the established windbreaks will be available without direct cost to individual farmers (32). A careful examination of the production cost and yield data indicated that acreage could be profitably expanded for only six commodities (passion fruit, tomatoes, Manoa lettuce, snap beans, cucumbers, and sweet potatoes). The remaining crops are omitted because of high production costs, in the project area, relative to recent price trends. One crop, guava, may offer expansion possibilities but it requires nearly five years to show a positive net return. Table 2 gives the cost per pound for the included crops with water priced at the announced eight cents per 1,000 gallons.

Demand Equations

Several equations, expressing the wholesale price of each vegetable crop as a function of different independent variables, were fitted to monthly data for the 10-year period ending in 1965. The best statistical fit was usually obtained with a linear multiple regression model, as specified by equation (1). This model is used for all of the vegetable crops except sweet potatoes and tomatoes which are imported in significant quantities from the U. S. Mainland.

(1) $P = f\ (QI, Y, M_i)$

where:

P = Honolulu wholesale price (cents per pound)

QI = Island grown Honolulu market supply (pounds per capita)

Table 2. Costs Per Pound and Yields Per Acre for Crops Under Study

Crop	Cost Per Pound		Yield[a]	
	LC_1	LC_2	LC_1	LC_2
	(cents)		(thousand pounds)	
Cucumbers	9.8	10.5	108	90
Manoa Lettuce	9.8	10.3	52	47
Snap Beans	19.7	20.9	36	32
Tomatoes	14.5	16.1	51	42
Passion Fruit	5.2	5.2	30	30
Sweet Potatoes	9.6	10.2	24	22

a/ Yield estimates are based on two crops per year for sweet potatoes and tomatoes, three crops for cucumbers, and four and five crops, respectively, for snap beans and Manoa lettuce. Passion fruit is planted in permanent orchards. These yields reflect the prevailing management practices now found in other areas of the State and should not be considered the highest obtainable in the Hoolehua area. For example, substantially higher tomato yields were recorded on the Molokai Demonstration Farm.

Table 3. Estimated Market Demand Equations[a]

Commodity	Equation	Constant	Q	Y	T	R^2	d[b]
Cucumbers	(3) OLS	30.0417	-23.3256 (7.06)[c]	-.0140 (.80)		.61	1.40
Manoa Lettuce	(4) OLS	17.1004	-40.8777 (6.71)	.0479 (3.29)		.56	1.50
Snap Beans	(5) OLS	43.9728	-66.3760 (8.11)	-.0207 (.78)		.64	1.21
Tomatoes	(6) OLS	17.3545	-2.9192 (1.54)	.0268 (1.63)		.41	1.12
Passion Fruit	(7) OLS	4.3887	- .0003[d]		.2558 (6.84)	.92	e/

a/ The coefficients for the monthly shifts are given in Appendix C.
b/ Durbin-Watson d statistic.
c/ The values in parentheses are t-ratios.
d/ Coefficient for total annual quantity.
e/ The d statistic was not computed as only eight observations are involved.

Y = Honolulu per capita personal income (dollars)

M_i = Variables for season (each variable takes the value of one for that month and zero for the other months; i = 1...12 for the months January...December, respectively)

There has not been enough variation in the market prices and quantities sold of sweet potatoes to provide a satisfactory estimate of the demand relationship. For the purposes of this study, a fixed price (perfectly elastic demand) is assumed with a total quantity restriction imposed in the estimating model.[2/] For tomatoes, the quantity variable represents the total market supply including imports from the U. S. Mainland.

A market demand relationship for passion fruit was estimated by fitting equation (2) to annual data for the eight-year period ending in 1965. Monthly data for this crop are not available.

(2) P = f (Q, T)

where:

P = Honolulu wholesale price (cents per pound)

Q = Honolulu market supply (thousand pounds)

T = Year (1...8)

The Durbin-Watson d statistic was computed for each of the vegetable demand curves, which were fitted by ordinary least squares (OLS). In every case this test indicated significant autocorrelation at the five percent level. The equations were re-estimated with the iterative least squares (ILS) procedure described by Johnston (18, pp. 194-199). These equations and the reasons for not using them in this study are discussed in Appendix C. The OLS equations are given in Table 3.

Supply Equations for Existing State Producers

Because the effect of price change on quantity supplied was of primary interest, a relatively simple supply model was selected. Equation (8) was fitted to monthly data for each of the vegetable crops except sweet potatoes. For sweet potatoes the variable Q represents total market supply from all sources (including the U. S. Mainland). This form is used because of the treatment of sweet potato demand.

(8) Q = f (P, T, M_i)

where:

Q = Honolulu market supply from state producers (1,000 pounds)

P = Honolulu wholesale price lagged one time period (cents per pound)

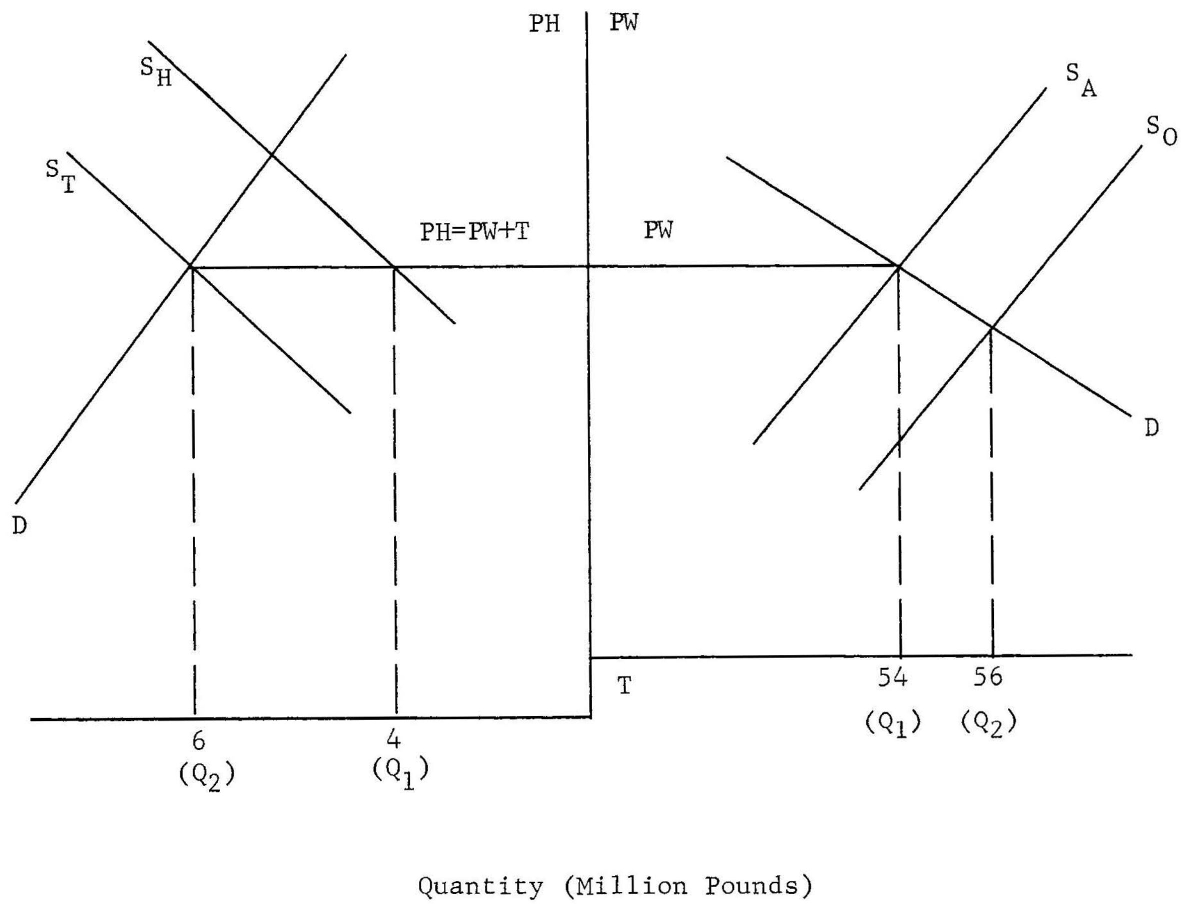
2/ This restriction represents the estimated additional quantity of sweet potatoes that could be sold during a given year without reducing price.

T = Year (1956-65)

M_i = Variables for season (each variable takes the value of one for that month and zero for the other months; i = 1...12 for the months January...December, respectively)

Tomatoes is the only other commodity that is imported in significant quantities from the U. S. Mainland. The market structure for tomatoes is such that state production could be expanded without depressing the Honolulu price until all imports are replaced. This structure is illustrated in Figure 2.

Figure 2. Theoretical market Structure for tomatoes.



where:

1. Hawaii is a deficit region importing Q_2 - Q_1 from the West Coast.

2. The West Coast is a surplus region exporting Q_2 - Q_1 to Hawaii. The figures given are approximate 1963 values for tomatoes in California and Hawaii. (Note that the quantity axis for the West Coast has a much larger scale than that of Hawaii.)

3. The equilibrium prices are PW for the West Coast and PW + T (transportation cost) for Hawaii. The West Coast supply curve has shifted from S_0 to S_A because of the exporting activity.

4. Expansion of local supply (S_H) could take place without significantly depressing price until local supply equals total market supply (S_T).

Table 4 gives the estimated supply functions that were used in the study. The different price lags were established by considering the growing period and the number of crops typically grown per year. In most cases these lags also give the best statistical fit. Although these equations leave much to be desired statistically they are an improvement over the only practical alternative which would be to assume a fixed quantity supplied over the price range being considered. Market price could vary from a maximum equal to the estimated equilibrium price without the project to a minimum which is the cost of production, including opportunity costs, on the highest quality land allocated to the production of the commodity being considered.[3/] It was not considered worthwhile to estimate the ILS version of equations (10), (11), and (13) for which d is significant. This decision is based on the difficulty of obtaining meaningful relationships consistent with the objectives of this study as discussed in Appendix C.

Table 4. Estimated Supply Functions for Existing State Producers[a/]

Commodity	Equation	Constant	P	T	R^2	d[b/]
Cucumbers	(9) OLS L[c/]=4	76.3499	1.5540 (1.53)[d/]	2.2935 (1.52)	.35	1.86
Manoa Lettuce	(10) OLS L=2	96.7812	.0489 (.08)	2.2364 (2.49)	.21	1.32
Snap Beans	(11) OLS L=3	306.970	.6026 (1.49)	-3.4712 (4.03)	.36	1.39
Tomatoes	(13) OLS L=6	81.884	3.2768 (1.28)	4.2237 (1.35)	.35	1.18
Sweet Potatoes	(12) OLS L=6	177.149	3.2560 (2.09)	-1.8316 (2.17)	.67	2.00

a/ A satisfactory supply relationship could not be estimated for passion fruit. The coefficients for the monthly shifts are given in Appendix C.
b/ Durbin-Watson d statistic.
c/ L is the lag in months associated with the price variable.
d/ The values in parentheses are t-ratios.

3/ A more elaborate supply analysis would have required a lengthy statewide survey because of the number of crops being considered. This would duplicate a survey now in progress which will estimate vegetable supply functions with a linear programming model. These functions will not be available for approximately two years.

DEMAND FOR IRRIGATION PROJECT WATER

To develop a factor demand curve from the model outlined earlier, it was necessary to modify some of the data. For 1965 the product demand curves were re-written to represent average annual price-quantity relationships assuming a Honolulu population of 568,000 people (3) and a per capita personal income of 226 dollars per month (8). The 1970 functions assume a population of 706,000 and a per capita income of 307 dollars per month.4/ The supply functions were similarly stated for inclusion in the estimating model. Production costs and yields were left unchanged, except for the price of water, in both years. Water was priced at seven, eight, and nine cents per 1,000 gallons plus a fixed assessment of $13.20 per acre per year because the slope of the function around the announced price of eight cents was of primary interest. The only restrictions imposed on the estimating model are land area and the quantity demanded of each commodity. Labor and capital which could be potentially restrictive are dealt with outside the model. A wage rate of $1.50 per hour is used which makes the diversified units competitive with the pineapple companies in the labor market. Capital, the second potential restriction, was found on closer investigation to pose no problem. State development programs for agricultural land have typically included provision for adequate credit at modest interest rates (31, p. 21).

Demand for Irrigation Water at Hoolehua, 1965

The first four crops (cucumbers, Manoa lettuce, snap beans, and tomatoes) were included in the model as previously outlined; that is, the functional relations for product demand and supply, and production costs and yields were entered into the model as data. In the case of passion fruit, a product supply function was not available so it was assumed that the observed 1965 quantity supplied by existing producers would remain unchanged over the price range being considered (3.4 million pounds with a price change from 5.4 to 5.1 cents per pound). For sweet potatoes, demand is assumed to be perfectly elastic at a price of 11 cents per pound, which has been the observed price for the past several years. However, a quantity restriction is imposed that equals the largest quantity previously supplied at the 11-cent price less the estimated quantity supplied in 1965 by existing producers.

The estimating model predicted the land use patterns given in Table 5 for each water price.

These land use patterns are for the most part self-explanatory. With the exception of passion fruit the crops show very little response to changes in the price of water. Sweet potato acreage does not change because of the way the crop was introduced into the model. None of the crops earn an economic rent because more than 200 acres of the most productive land remains idle (see Tables 1 and 5). An economic rent is earned only when the best land becomes restrictive forcing production onto lower quality land. A net return, which equals the net price per pound multiplied by yield, was assigned to sweet potato production on land classes LC1 and LC2. Because this treatment of sweet potatoes is a substitute

4/ Population and income estimates for 1970 were supplied by the Department of Economic Development, State of Hawaii, Honolulu, Hawaii.

for a demand function which would have permitted production to the point of zero rent this return cannot be viewed as an economic rent.

Table 5. Estimated Land Use Patterns for Selected Water Prices, 1965

Crop	Land Crop	Price of Water		
		7	8	9
		(Acres)	(Acres)	(Acres)
Cucumbers	LC1 LC2	20.0	19.9	19.9
Manoa Lettuce	LC1 LC2	27.5	27.4	27.3
Snap Beans	LC1 LC2	25.3	25.2	25.1
Tomatoes	LC1 LC2	343.8	342.2	340.8
Passion Fruit	LC1 LC2	31.9	24.1	16.3
Sweet Potatoes	LC1 LC2	11.5	11.5	11.5
Total (LC1)		460.0	450.3	440.9

Equation (14) in Figure 3 is the derived 1965 water demand function for Hoolehua. The addition to total tomato acreage associated with these land use patterns was substantial. Total market supply was estimated at 22 million pounds with the project compared with an observed 1965 supply of about 8 million pounds. This increase in quantity supplied was accompanied by a price decline of 7.8 cents per pound. At this new price project producers can still cover costs and existing island producers would supply about 5 million pounds. The tomato demand function used in this study requires large quantity increases before price is significantly reduced. However, the regression coefficient for quantity is nearly identical to those of two alternative functions (9, 25). The former of these in which price is a function of total quantity, month, and year was recomputed for the study period and found to have quantity coefficient of .0005 as compared to .0004 for equation (7) when both were stated as annual average price-quantity relationships. The equilibrium market prices are given in Table 6.

Demand for Irrigation Water at Hoolehua, 1970

The only data changes for 1970 were in the commodity supply and demand functions. These modifications were described earlier. Passion fruit supply is

Table 6. Estimated Product Prices for Each Land Use Pattern

	Price of Water		
	7	8	9
	(cents per pound)		
Cucumbers	9.7	9.8	9.8
Manoa Lettuce	9.8	9.8	9.8
Snap Beans	19.6	19.7	19.7
Tomatoes	14.5	14.5	14.5
Passion Fruit	5.1	5.2	5.3
Sweet Potatoes	11.0	11.0	11.0

Table 7. Estimated Land Use Patterns for Selected Water Prices, 1970

Crop	Land Class	Price of Water		
		7	8	9
		(acres)		
Cucumbers	LC1	24.2	24.1	24.0
	LC2			
Manoa Lettuce	LC1	21.2	23.6	26.0
	LC2	35.4	32.6	29.8
Snap Beans	LC1	36.4	36.2	36.1
	LC2			
Tomatoes	LC1	596.3	594.1	591.9
	LC2			
Passion Fruit	LC1			
	LC2	173.0	165.2	157.4
Sweet Potatoes	LC1			
	LC2	12.4	12.4	12.4
Total	LC1	678.0	678.0	678.0
	LC2	220.8	210.2	199.6

again fixed at 3.4 million pounds based on a simple linear trend that provides this estimate of quantity supplied in 1970. As this is equal to the quantity actually observed in 1965, it is used in both years.

Table 7 shows the land use patterns estimated for 1970. The water demand function derived from these patterns is given in Figure 3 as equation (15). The results have the same interpretation as those given for 1965. The most substantial changes occurred in the acreages estimated for tomatoes and passion fruit with the latter registering the largest relative change. In this example, a per acre rent increment equal to \$236, \$238, and \$240 accrues to land class LC1 when water is priced at seven, eight, and nine cents per 1,000 gallons, respectively. Land class LC2 does not earn a rent because it is never restrictive. The equilibrium market prices for the different commodities and land use patterns are given in Table 8.

Seasonality of Water Requirements

The derived water demand curves show the total quantity of water that could be sold to diversified crop producers, at alternative prices, in a given year. While this result is meaningful, it would be desirable to know how much of this total would be needed in a particular month. In this section a procedure for approximating the monthly requirements will be outlined.

It is expected that the monthly quantity marketed by project producers will remain fairly constant throughout the year. For example, 20 acres of cucumbers to be grown in the project area would imply harvesting 5 acres per month given the assumed practice of producing three crops per year. The monthly water requirements of Appendix B can be stated as percentages of the net annual requirement then used with the gross annual requirement (from the demand curve) to approximate the monthly requirements. This assumes that the acreage of each crop will not be changed during the year. Similar assumptions have already been made for production costs, yields, gross water requirements, and the pattern of marketing for existing and project producers. Table 9 gives the estimated monthly water requirements expressed both as a percentage of the total requirement and in millions of gallons.

Applicability of Study Results to Other Producing Areas on Molokai

The Hawaiian Homes Commission lands located at Hoolehua represent another area that is likely to use significant quantities of project water for diversified crop production. Most of the land in this and the study area has the same productivity for vegetable production (1). Therefore, within the framework of stated assumptions and limitations accompanying the foregoing analysis, the study results are directly applicable to the Hawaiian Homes Commission lands.

One qualification must be made, however. The land use patterns associated with the different water prices represent the new acreage that could be brought into production under existing conditions. If the Department of Land and Natural Resources or the Hawaiian Homes Commission should independently develop several hundred acres for diversified crop production, the other agency would be well advised to consider their development plans carefully. Because of this interdependence the two agencies should perhaps plan together and mutually develop diversified crop acreage to utilize the newly acquired water resources.

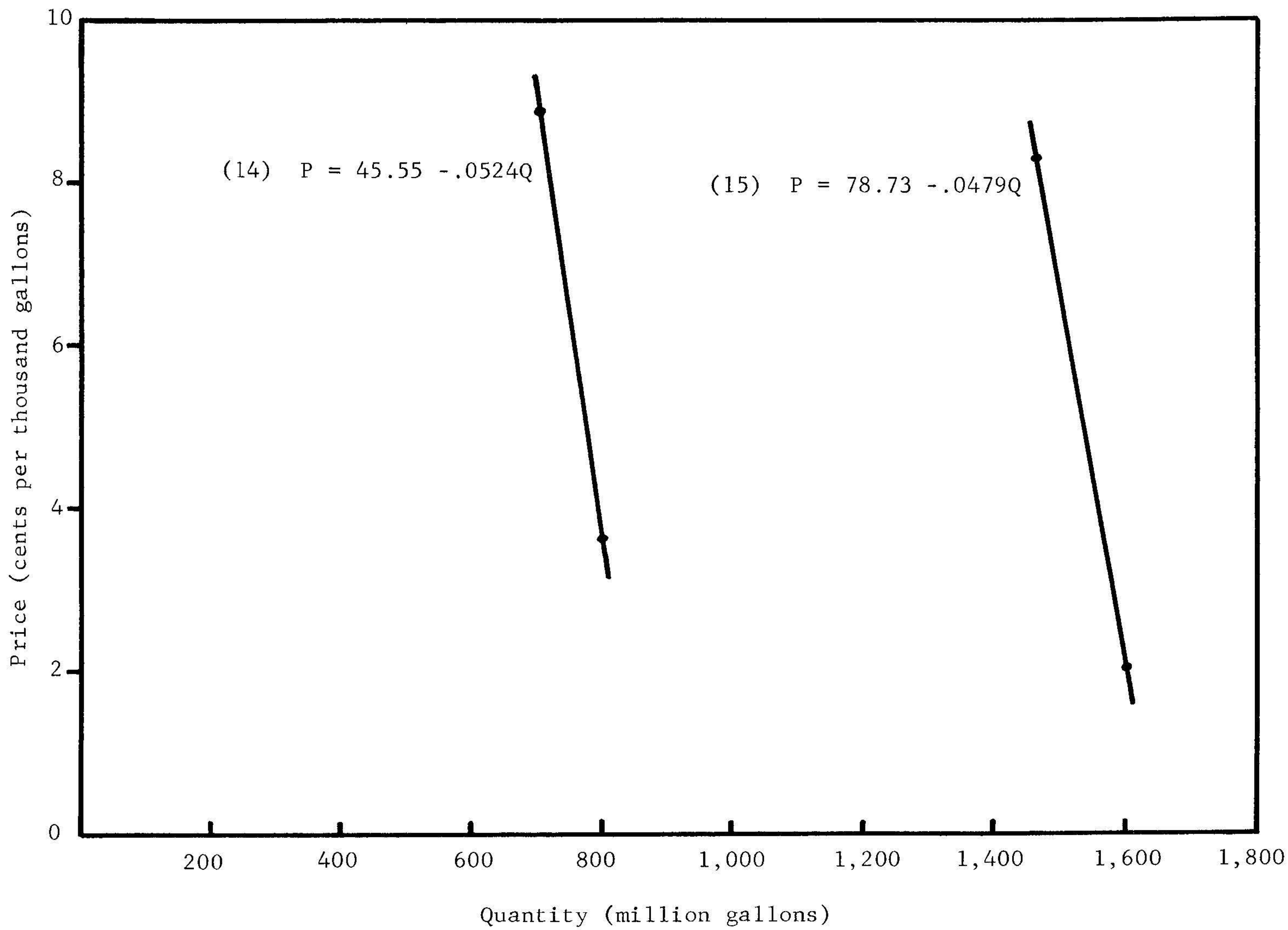


Figure 3. Derived demand curves for Molokai irrigation project water, 1965 and 1970.

Table 8. Estimated Product Prices for Each Land Use Pattern

Crop	Price of Water		
	7	8	9
	(cents per pound)		
Cucumbers	10.0	10.0	10.0
Manoa Lettuce	10.2	10.3	10.3
Snap Beans	20.3	20.3	20.4
Tomatoes	14.9	15.0	15.0
Passion Fruit	5.1	5.2	5.3
Sweet Potatoes	11.0	11.0	11.0

Table 9. Approximate Monthly Water Requirements for the Project Land[a/]

Item	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Percent	3	5	3	8	11	12	14	14	11	10	7	3
Million gallons (1965)	22	36	22	57	79	86	100	100	79	72	50	22
Million gallons (1970)	44	74	44	118	162	177	207	207	162	148	103	44

a/ Water is priced at eight cents per 1,000 gallons. These estimates were derived from the data in Appendix B for crop group one which represents most of the acreage.

SOME ECONOMIC EFFECTS OF EXPANDED PRODUCTION ON EXISTING STATE PRODUCERS, THE STATE AS A WHOLE, AND THE CONSUMER

It follows from what has already been said about the sensitivity of Honolulu market price to quantity change, that development of the project land will work to the disadvantage of existing state producers. What is not so obvious is that the consumer and the state as a whole may benefit, perhaps greatly, from such a development. The purpose of this section is to examine some of the measurable changes that would have occurred in 1965 had the land been made available with water priced at eight cents per 1,000 gallons.

Changes in Producer and State Output

The estimated changes in output that would have accompanied the project in 1965 are indicated in Table 10.

The reduction in quantity supplied by existing producers results from their moving down their respective supply curves because of the reduced prices. This reduction in quantity supplied is insignificant. However, total state production has increased substantially in every case.

Changes in Producer and State Income

Although the output of existing producers is expected to change only slightly their income was substantially reduced. Estimated changes in existing producer and state incomes are given in Table 11.

Table 10. Estimated Changes in Existing Producer and State Output

Crop	Existing State Production[a]	Projected State Production	Change in Output for Existing Producers
		(thousand pounds)	
Cucumbers	3,015	5,040	- 127
Manoa Lettuce	1,602	3,022	- 5
Snap Beans	1,178	2,025	- 59
Tomatoes	5,075	22,305	- 228
Passion Fruit	3,400	4,122	--
Sweet Potatoes	660	933	--

a/ Estimated from the supply and demand functions for all crops except sweet potatoes where the actual 1965 production is used.

Table 11. Estimated Changes in Income for the State and Existing Producers

Crop	Existing Gross State Income	Projected Gross State Income	Projected Gross Income for Existing Producers
		(dollars)	
Cucumbers	500,000	494,000	283,000
Manoa Lettuce	293,000	296,000	156,000
Snap Beans	327,000	399,000	220,000
Tomatoes	1,030,000	3,234,000	703,000
Passion Fruit	184,000	214,000	177,000
Sweet Potatoes	73,000	103,000	73,000
Total	2,407,000	4,740,000	1,612,000

The material provided in Table 11 indicates that the gross income received by existing state producers declined one-third to about $1.6 million. Total state income on the other hand increased nearly 100 percent to $4.7 million.

Changes in the Wholesale Price Level

Changes in the wholesale prices of most included commodities would be expected if the project becomes a reality. While a detailed evaluation of how these changes might affect retail prices and consequently the consumer is beyond the scope of this study, an approximation can be made. For convenience, it is assumed that the retail margin is constant; that is, a one-cent drop in price at the wholesale level would reduce retail price by a like amount. The expected price changes associated with the project are given in Table 12.

Table 12. Estimated Wholesale Price Changes

Item	Cucumbers	Manoa Lettuce	Snap Beans	Tomatoes	Passion Fruit	Sweet Potatoes
Existing Price[a]	16.6	18.3	27.8	20.3	5.4	11.0
Estimated Price with Project	9.8	9.8	19.7	14.5	5.2	11.0

a/ Existing prices are estimated from the supply and demand equations.

SUMMARY AND IMPLICATIONS

Competitive land use patterns were estimated, with water priced at alternative rates, for both 1965 and 1970. This analysis indicated that diversified producers operating 25-acre units could utilize approximately 450 acres of the project land in 1965 and nearly double that amount by 1970. This increase in acreage results from estimated changes in population and consumer income and assumes that practically all of the additional production will come from Molokai.

The water demand curves associated with the land use patterns indicate that a five-cent reduction in the price of water would be required to sell 100 million additional gallons per year.[5] In other words, water price has little effect on the quantity of water demanded.[6] The supply of available water is sufficient to meet diversified crop requirements throughout the year. The quantity of available water is estimated at 2.5 billion gallons per year and uniform seasonal deliveries will be possible after the storage reservoir has been completed. In 1965 diversified crops could have utilized 28 percent of the available water.

5/ The coefficients of price elasticity at eight cents per 1,000 gallons are .21 and .11 for the 1965 and 1970 functions, respectively.

6/ This is not a surprising result as water accounts for a very small portion of total production costs, e.g., about two percent of the total production cost for tomatoes.

If the project land had been made available in 1965, existing producer output would have been only slightly reduced but their gross income would have fallen nearly $800,000. Gross state income on the other hand would have increased from $2.4 to $4.7 million. A substantial reduction in wholesale prices accounts for most of this income loss and would probably affect retail prices as well.

While this report was being prepared, 350 acres of LC1 were leased to a single operator for Irish potato production. This crop was deleted from the present study because it was unprofitable when considered in terms of a 25-acre unit. The effect of this large lease to a single producer on the results of this investigation are obvious. The land use patterns developed for 1965 would use the remaining LC1 and perhaps 100 acres of LC2. By 1970 all of both land classes could be utilized and as LC2 would be exhausted, it would also earn an economic rent. This change in the availability of land was not considered in this report because it occurred after the analysis had been completed. The study results are fully applicable to the Hawaiian Homes Commission lands at Hoolehua.

APPENDIX A

The following land type descriptions are from the detailed land classification reports (1, 30) published by the Land Study Bureau, University of Hawaii.

Land Type	Description
1	Deep, red (Molokai) soils; nonstony to slightly stony; slopes less than 10%; average annual rainfall (AAR) less than 20 inches; moderate to strong winds.
3	Moderately deep, red (Molokai) soils; stony; slopes less than 10%; AAR less than 25 inches; moderate to strong winds.
7	Moderately deep, red (Molokai and Lahaina) soils; slopes less than 40%; eroded; AAR less than 25 inches.
17	Moderately deep; nonstony to slightly stony; dark (Kawaihapai and Hanalei) soils; nearly level coastal flat areas.

Table B-1. Irrigation Requirements for Study Crops Grown at Hoolehua, Molokai

Month	Pan Evaporation[a/] (E)	Average Consumptive Use Coefficients[b/] (K)		Gross Requirement (K)·(E)		Rainfall		Irrigation Requirement	
		Crop Group 1	Crop Group 2	Crop Group 1	Crop Group 2	Total	Effective	Crop Group 1	Crop Group 2
	(inches per month)			(inches)	(inches)	(inches)	(inches)	(inches)	(inches)
January	5.70	.60	.55	3.42	3.14	3.2	1.9	1.52	1.24
February	5.80	.60	.55	3.48	3.19	2.1	1.1	2.38	2.09
March	5.76	.60	.55	3.46	3.17	2.8	1.9	1.56	1.27
April	7.70	.60	.55	4.62	4.24	1.1	.7	3.92	3.54
May	10.53	.60	.55	6.32	5.79	.8	.7	5.62	5.09
June	10.06	.60	.55	6.04	5.53	.2	--	6.04	5.53
July	12.75	.60	.55	7.65	7.01	.6	.5	7.15	6.51
August	12.78	.60	.55	7.67	7.03	.5	.4	7.27	6.63
September	9.80	.60	.55	5.88	5.39	.3	--	5.88	5.39
October	9.77	.60	.55	5.86	5.37	1.0	.9	4.96	4.47
November	8.20	.60	.55	4.92	4.51	2.4	1.3	3.62	3.21
December	5.66	.60	.55	3.40	3.11	3.0	1.9	1.50	1.21
Average								4.28	3.85

a/ Pan Evaporation data obtained from the Department of Land and Natural Resources, State of Hawaii.
b/ Crop Group 1 includes: cucumbers and tomatoes. Crop Group 2 includes: passion fruit, sweet potatoes, snap beans, and Manoa lettuce.

Table B-2. Water Required Per Acre Per Year

Crop	Months Grown Per Year[a]	Net Requirement	Gross Requirement[b]	Cost of Water[c]	Assessment[d]
		(inches)	(inches)	(dollars)	(dollars)
Cucumbers	9 (3 crops)	38.52	64.20	139	13
Manoa Lettuce	10 (5 crops)	38.50	64.17	139	13
Snap Beans	8 (4 crops)	30.80	51.33	112	13
Tomatoes	8 (2 crops)	34.24	57.07	124	13
Passion Fruit	12 (1 crop)	46.20	77.00	167	13
Sweet Potatoes	9 (2 crops)	34.65	57.75	125	13

a/ Based on prevailing management practices.
b/ Assumes 60 percent efficiency.
c/ Based on the announced price of eight cents per 1,000 gallons.
d/ Announced annual per acre assessment for all diversified crop land being serviced by project.

APPENDIX C

Demand Equations

The seasonal shift variables were included because of a pronounced seasonal pattern in the estimated price-quantity relationships. According to Foytik (10) these shifts, which are known to exist for many perishable commodities, result from a combination of influences that are difficult to quantify. In the present case the shifts probably occur from intraseasonal changes in the prices of a number of competing products. However, including different product prices as explanatory variables did not result in regression coefficients that were significant at the five percent level. Because of this, when an intraseasonal demand shift appeared, month was used as a "proxy" for the variables actually causing the shift. This procedure results in a set of regression coefficients that, when plotted, trace out a seasonal pattern identical to that isolated by graphic methods (9, pp. 25-29). These shifts are given in Table C-1.

A first-order autoregressive structure was assumed for estimating the ILS equations. This scheme is specified by Equation (16).

$$(16) \quad U_t = \alpha + \rho \ U_{t-1} + V_t$$

where:

U_t = Autocorrelated disturbance term from equation (1)

Table C-1. Monthly Shifts for the Vegetable Demand Functions[a/]

Crop	January	February	March	April	May	June	July	August	September	October	November	December
Cucumbers	2.8856	4.6178	2.4662	- .6843	-2.3062	-2.7918	-2.0831	-1.7634	-1.0345	- .4951	1.4837	- .2945
Manoa Lettuce	.3323	1.5766	.3512	-3.3736	-2.0707	-1.5459	- .5040	1.4710	- .2203	1.7245	2.3406	- .0820
Snap Beans	1.9195	2.2377	4.3750	-2.1684	-3.9857	-4.7796	.2935	- .5568	.1762	.2566	.9364	1.3029
Tomatoes	2.1872	2.8857	2.9378	1.3751	- .3588	- .0941	-1.7092	-3.4137	-3.5565	-2.7206	.0737	2.3932

a/ These shifts are for the OLS functions presented in the text.

ρ = Coefficient of Autocorrelation

V_t = A random variable with zero mean and a constant variance

The resulting equations and the OLS equations are given in Table C-2. Taking the iterative procedure through the first stage resulted in a non-significant d for Manoa lettuce (4) and tomatoes (6), an indeterminate d for snap beans (5), and a significant d for cucumbers (3).[7/]

In the case of equation (3) the d statistic is still significant at the five percent level and is only slightly larger than the d for the OLS version. The coefficients for the two versions of equation (4) are not significantly different, therefore, the equation with the higher R^2 is to be preferred. The main difficulty with equation (5) is the 20 percent reduction in R^2 while achieving only an indeterminate d at the five percent level. The ILS version of equation (6) may have some merit but again the loss in R^2 is substantial (10 percent). Perhaps a better indication of the relative soundness of these equations is their ability to predict price. The equations were rewritten to represent the average annual price-quantity relationship for the years 1963, 1964, and 1965. Solving these equations with the actual market supplies for each year yields estimates of the annual average market price for each crop. The OLS estimates were nearer the observed prices in two out of three years for equations (3), (4), and (5). The OLS version of equation (6) gave the best estimate in all three years.

The seasonal shifts employed in these functions probably increase the serial correlation present in the residuals. This could result from slight changes in the seasonal pattern over the study period which are not provided for in the function. Even more troublesome is the cyclical nature of these shifts which could result in periods of positive followed by negative serial correlation which would be very difficult to remove. This possibility was explored further by comparing d statistics for three equations (Manoa lettuce, snap beans, and tomatoes) employing a single within-year shift. The computed values were 1.45, 1.62, and 1.33, respectively. Unfortunately, these functions contained a time variable (year) so it is not clear why the d's indicate less serial correlation.

In view of the considerations discussed in this section it appears that the OLS version of the vegetable crop functions is preferable for the purposes of this study. The demand relation for passion fruit is represented by equation (7). This function was fitted by OLS and a d statistic was not computed.

Supply Equations

The justification for using monthly shift variables for a seasonally shifting supply function is not as straightforward as it was in the case of demand. In Hawaii, the monthly marketings of the different vegetables are relatively constant throughout the year. This means that, in the aggregate, planting decisions are constantly being made. Consequently, a lagged price

7/ Theil and Nagar (35) point out that the tabulated probabilities for d are of limited value when used with the ILS functions because they are conditional upon the results of the OLS functions.

variable could have a different effect on quantity supplied during different periods of the year. As these periods are not known for the several vegetables being considered, the monthly shifts offer a convenient substitute. These shifts are given in Table C-3.

Table C-2. Estimated Market Demand Equations[a/]

Commodity	Equation	Constant	Q	Y	T	R^2	d[b/]
Cucumbers	(3) OLS	30.0417	-23.3256 (7.06)[c/]	-.0140 (.80)		.61	1.40
	ILS	24.7174	-18.7473 (6.09)	.0028 (.14)		.54	1.54
Manoa Lettuce	(4) OLS	17.1004	-40.8777 (6.71)	.0479 (3.29)		.56	1.50
	ILS	17.5425	-40.5505 (6.67)	.0499 (2.98)		.53	1.83
Snap Beans	(5) OLS	43.9728	-66.3760 (8.11)	-.0207 (.78)		.64	1.21
	ILS	21.9502	-28.5129 (3.48)	.0645 (1.99)		.44	1.63
Tomatoes	(6) OLS	17.3545	- 2.9192 (1.54)	.0268 (1.63)		.41	1.12
	ILS	8.5271	- .5450 (.39)	.0386 (2.15)		.32	1.74
Passion Fruit	(7) OLS	4.3887	- .0003[d/] (2.13)		.2558 (6.84)	.92	e/

a/ The coefficients for the monthly shifts are given in Table C-1.
b/ Durbin-Watson d statistic.
c/ The values in parentheses are t-ratios.
d/ Coefficient for total annual quantity.
e/ The d statistic was not computed as only eight observations are involved.

Table C-3. Monthly Shifts for the Vegetable Crop Supply Functions[a/]

Crop	January	February	March	April	May	June	July	August	September	October	November	December
Cucumbers	-47.8965	-47.9519	-14.1788	40.2198	43.2704	9.7283	4.6085	14.2352	24.8209	.2388	- 4.7350	-22.4147
Manoa Lettuce	- 6.4662	-21.1386	17.6111	6.9299	11.6088	13.4285	- 1.7115	4.5670	- 4.6215	.0767	- 12.2699	- 7.8603
Snap Beans	-17.0000	-24.909	7.621	22.698	15.960	- 1.683	6.886	7.300	7.132	5.294	- 6.584	-22.719
Tomatoes	23.246	-27.751	14.023	63.984	100.640	51.438	27.620	-57.399	-125.977	-86.051	- 43.198	59.426
Sweet Potatoes	-27.152	-21.563	-10.722	- 8.813	1.641	-13.852	-26.203	-19.868	- 1.968	1.590	90.743	36.169

a/ These shifts are for the OLS functions presented in the text.

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